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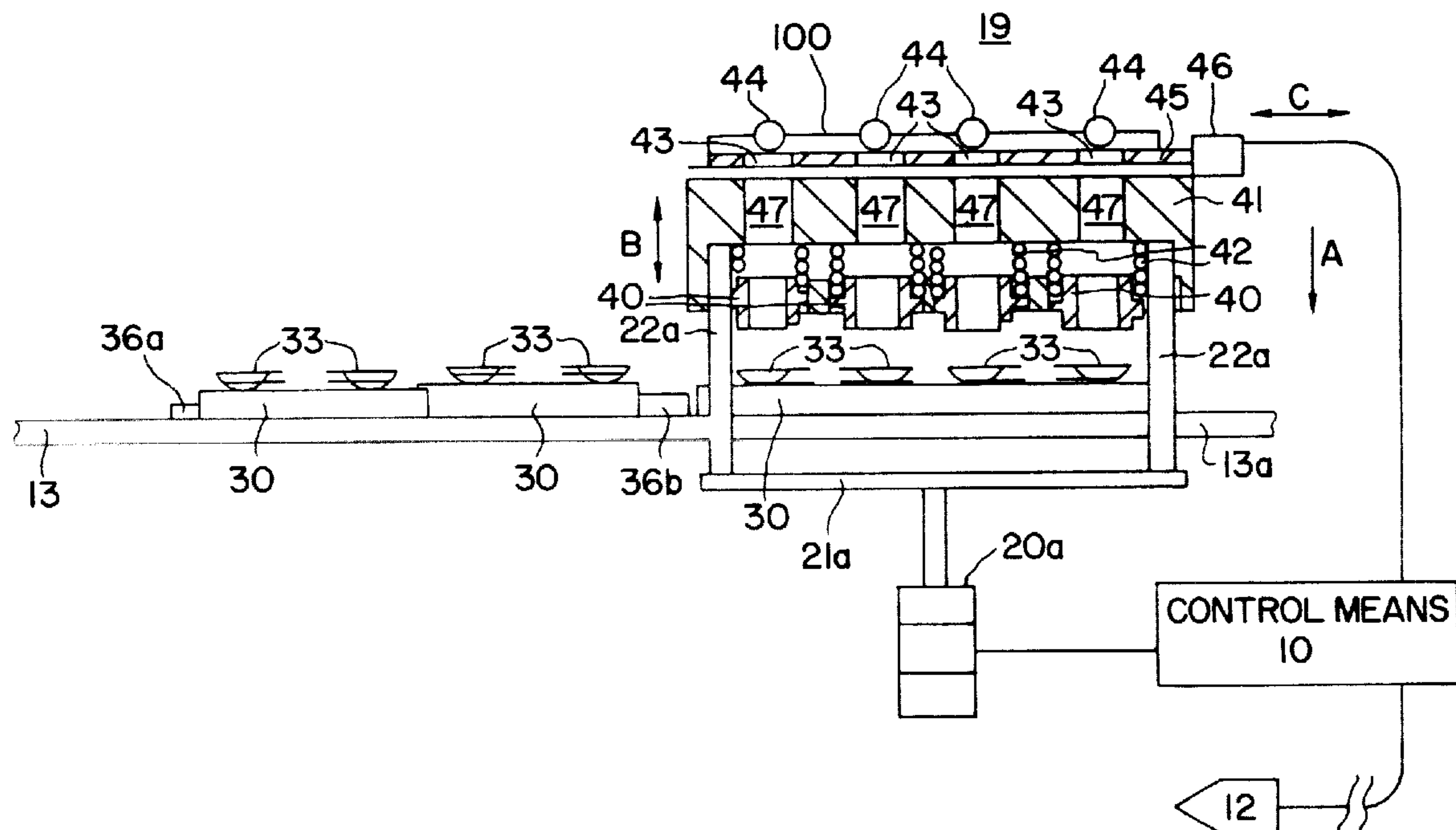
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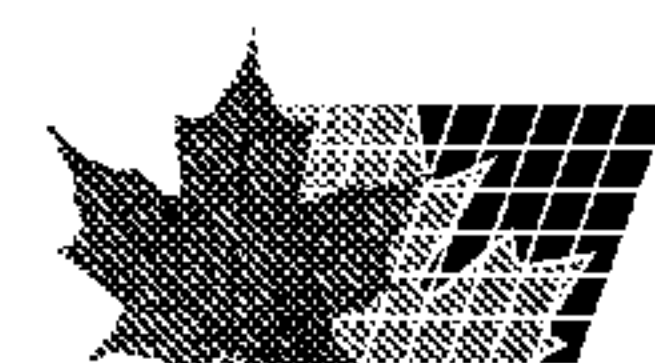
(54) Titre : SERRAGE DE MOULE ET PRECUSSION D'UN HYDROGEL POLYMERISABLE

(54) Title: MOLD CLAMPING AND PRECURE OF A POLYMERIZABLE HYDROGEL



(57) Abrégé/Abstract:

An apparatus and method for partially curing a polymerizable monomer or monomer mixture to form a soft contact lens includes a transport device for transporting a plurality of contact lens molds to a precure station in a low oxygen environment, each contact lens mold including a first and second mold half with a polymerizable monomer or monomer mixture therebetween. A clamping member clamps a first contact lens mold half against a second contact lens mold half for a predetermined pressure and time. While the mold halves of the contact lens mold are clamped, the polymerizable monomer or monomer mixture is exposed to a radiant energy source for polymerizing the polymerizable monomer or monomer mixture contained in each contact lens mold.



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ABSTRACT OF THE DISCLOSURE

An apparatus and method for partially curing a polymerizable monomer or monomer mixture to form a soft contact lens includes a transport device for transporting a plurality of contact lens molds to a precure station in a low oxygen environment, each contact lens mold including a first and second mold half with a polymerizable monomer or monomer mixture therebetween. A clamping member clamps a first contact lens mold half against a second contact lens mold half for a predetermined pressure and time. While the mold halves of the contact lens mold are clamped, the polymerizable monomer or monomer mixture is exposed to a radiant energy source for polymerizing the polymerizable monomer or monomer mixture contained in each contact lens mold.

MOLD CLAMPING AND PRECURE
OF A POLYMERIZABLE HYDROGEL

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates generally to an apparatus and method for molding soft contact lenses, and particularly an apparatus and method for precuring a polymerizable monomer or monomer mixture under pressure to form a soft contact lens.

2. Discussion of the Prior Art.

U.S. Patent 4,495,313 to Larsen, now assigned to the assignee of the present application, discloses the polymerization of a monomer to form a soft contact lens by means of ultraviolet light. In addition, this reference also teaches that an ultraviolet light catalyst can be added to the polymerization system to effect an essentially complete polymerization.

U.S. Patent 5,039,459 to Kindt-Larsen et al. entitled "Method of Forming Shaped Hydrogel Articles Including Contact Lenses" teaches the polymerization of soft contact lenses wherein the monomer/diluent mixture in a transparent polystyrene mold is exposed on one side to 1.7 jewels/centimeter squared of ultraviolet radiation for ten minutes at 55°C (TL 09 lamps with peak radiation at 350 nm).

In addition to these two references, U.S. Patents 4,565,348; 4,680,336; 4,640,489 and 5,080,839 all disclose the polymerization of a monomer with ultraviolet light to form a soft contact lens.

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SUMMARY OF THE INVENTION

The present invention is an apparatus and a method for precuring a polymerizable monomer mixture to form a soft contact lens in a mold which enables a more uniform cure for the lens during the cure step, and which reduces "puddling" or cavitation of the lens in the mold during cure.

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In one aspect, the present invention provides an apparatus for partially curing a polymerizable monomer or monomer mixture to form a soft contact lens, the apparatus comprising: a clamping member for clamping a first contact lens mold half against a second contact lens mold half at a precure station for a predetermined pressure and time, the first and second mold halves having a polymerizable monomer or monomer mixture therebetween; a radiant energy source for polymerizing the polymerizable monomer or monomer mixture while the first and second halves are clamped together, wherein the radiant energy source is movable from a first transport position to a second exposure position for polymerizing the monomer or monomer mixture; and a frame for moving the radiant energy source from the first transport position to the second exposure position.

20

In another aspect, the present invention provides a method of partially curing a polymerizable monomer or monomer mixture to form a soft contact lens, the method comprising: depositing a polymerizable monomer or monomer mixture in a contact lens mold having a first and a second half with the monomer therebetween; clamping the first mold half into engagement with the second mold half with a predetermined pressure; moving a radiation source from a first transport position to a second exposure position for polymerizing the monomer or monomer mixture, the radiation source being moved by means of a frame; and exposing the monomer or

25

- 2a -

monomer mixture to the radiation source to polymerize the monomer to a partially cured state.

In yet another aspect, the present invention provides a method of curing a polymerizable monomer or monomer mixture to form a soft contact lens, the method comprising: depositing a polymerizable monomer or monomer mixture in a contact lens mold having a first and a second half with the monomer therebetween; clamping the first mold half into engagement with the second mold half with a predetermined pressure; moving a radiation source from a first transport position to a second exposure position for polymerizing the monomer or monomer mixture, the radiation source being moved by means of a frame; and exposing the monomer or monomer mixture to radiation to polymerize the monomer to a cured state.

In yet another aspect, the present invention provides a method of partially curing a polymerizable monomer or monomer mixture to form a soft contact lens, using an apparatus comprising: a transport for intermittently transporting a plurality of contact lens molds through a precure station, each of the contact lens molds having first and second mold halves with a polymerizable monomer therebetween; a clamping member for clamping the first mold half against the second mold half for a predetermined pressure and time; a radiant energy source for polymerizing the polymerizable monomer while the first and second halves are clamped together; and a control circuit for setting the predetermined pressure and time.

In yet another aspect, the present invention provides a method of curing a polymerizable monomer or monomer mixture to form a contact lens, the method comprising the steps of: depositing a polymerizable monomer or monomer mixture in a contact lens mold having a first and a second half with the monomer therebetween, each of the mold halves having an annular flange; clamping the first mold half into engagement with the second mold half with a predetermined pressure with the annular flanges of the mold halves substantially parallel; moving a radiation source from a first transport position to a second exposure position for polymerizing the monomer or monomer mixture, the radiation source being moved by means of a frame; exposing the monomer or monomer mixture to radiation to polymerize the monomer to a partially cured state to seal the mold halves together, in alignment, for a subsequent cure step.

-2b-

In accordance with the present invention, suitably a polymerizable monomer or monomer mixture is deposited in a lens mold having first concave and second convex mold halves. The mold halves are formed of polystyrene or other material transparent to actinic or visible radiation. The mold halves are transported from the deposition and mold assembly station to the precure station of the present invention, and clamped together under predetermined pressure for a predetermined period of time which may be done in a low oxygen environment. The second or convex mold half may be slightly thinner than the first or concave mold half to enable mold compliance during cure as the monomer is polymerized. The clamping pressure aligns flanges formed on the first and second mold halves to ensure that the flanges are parallel and that the respective curves of the molds are aligned. The clamping pressure also seats the second convex mold half against an annular edge formed on the first mold half to essentially sever any excess monomer from the monomer contained within the mold.

After a predetermined clamping period, the hydrogel is exposed to actinic or visible radiation, such as a UV light source, to partially cure the hydrogel to a gel state. After a second predetermined period of

exposure under clamping pressure, the clamping action and
1 the UV radiation may be removed, and the partially
precured hydrogel lens is transported in the mold to a
curing station for complete polymerization and cure.
Alternately, a complete cure may be effected in the
5 apparatus.

It is an object of the present invention to
provide a novel means for precuring a polymerizable
monomer or monomer mixture to form a soft contact lens.
The means includes a transport for intermittently
10 transporting a plurality of contact lens molds to the
precure station in a low oxygen environment. The contact
lens molds include first and second mold halves with a
polymerizable monomer or monomer mixture therebetween.
The means also include a plurality of means for clamping
15 the first mold half to the second mold half for a
predetermined period of time in a low oxygen environment.
The polymerizable monomer or monomer mixture is then
exposed to actinic radiation for a predetermined period of
time while it is under pressure to partially or completely
20 cure the monomer or monomer mixture.

The clamping pressure may be applied by an
annular air cylinder, spring driven annular cylinder, or
physical weights which allows actinic radiation to pass
through the annulus of the cylinder and through one or
25 more of the mold halves and into the monomer or monomer
mixture. The means may include a means for controlling
the duration and intensity of the clamping pressure, and
the duration and intensity of the actinic radiation.

Another object of the present invention is to
30 provide a novel method of precuring a polymerizable
monomer or monomer mixture to form a soft contact lens.
The method includes a step of depositing a polymerizable
monomer or monomer mixture in a contact lens mold having
first concave and second convex mold halves with the

monomer therebetween. The mold halves are then clamped
1 together with a predetermined pressure and then exposed to
radiation to partially polymerize the monomer to a
precured gel-like state. The clamping pressure is then
relieved and the lens is then cured with additional
5 radiation or a combination of heat and radiation.

In the preferred embodiment the radiation source
may be actinic, electron beam or radioactive source, but
preferably is an ultraviolet lamp which irradiates the
monomer at 2-4 mW/cm² for 5-60 seconds, but preferably 20-
10 40 seconds. Radiation may also be from a high intensity
UV source that is pulsed or cycled.

The clamping step aligns the mold halves, causes
excess monomer to be removed from the mold cavity, and
seats a compliant second mold half against a first mold
15 half for the precure step.

It is an object of the present invention to
precure a polymerizable monomer or monomer mixture to a
gel-like state wherein polymerization has been initiated
throughout the monomer, and utilize the shrinkage of the
monomer and the compliance of the mold halves to seal and
20 hold the mold halves together for the remainder of the
cure period.

It is another object of the present invention to
precure the hydrogel in a low oxygen environment to
25 prevent undesired absorption of oxygen by the monomer.

It is another object of the present invention to
provide an adjustable means for varying the clamping
pressure during the precure step.

It is another object of the present invention to
30 provide a reciprocating means for positioning the actinic
light source at an exposure position, and then retracting
the light source to a second position for transport of the
lens molds.

It is further an object of the present invention
1 to provide an alternate reciprocating means for
positioning the lens molds against the light source for
exposure, and retracting the molds to a second position
for transport.

5

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing objects and advantages of the
present invention for precuring a polymerizable monomer or
10 monomer mixture may be more readily understood by one
skilled in the art with reference to the following
detailed description of the two preferred embodiments,
taken in conjunction with the accompanying figures wherein
like elements are designated by identical reference
15 numerals throughout the several views.

Figure 1 is a partially cut away elevation view
of one of the embodiments for precuring a polymerizable
monomer or monomer mixture to form a soft contact lens.

Figure 2 is an end elevational view of the
20 apparatus illustrated in Figure 1.

Figure 3 is a diagrammatic and schematic
illustration of one embodiment of the invention.

Figure 4 is a plan view of a carrier used to
transport a plurality of contact lens molds having a
25 polymerizable monomer or monomer mixture therebetween to
and from the precure station.

Figure 4(a) is a diagrammatic and cross-
sectional view of a pair of mold halves in the pallet
carrier of Figure 4.

30 Figure 5a is a diagrammatic illustration of one
embodiment of the present invention which uses an air
driven clamp for clamping the mold halves together.

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Figure 5b is a diagrammatic illustration of a
1 second embodiment of the present invention which uses a
spring driven clamp for clamping the mold halves together.

Figure 6 is a plan view of a reciprocating
portion of the apparatus for precuring a polymerizable
5 monomer or monomer mixture to form a contact lens.

Figure 7 is an elevational view of the apparatus
illustrated in Figure 6.

Figure 8 is an end elevational view of the
apparatus illustrated in Figure 6.

10 Figure 9 is an elevational end view of a second
embodiment of the present invention used to precure a
polymerizable monomer or monomer mixture to form a soft
contact lens.

Figure 10 is an elevational side view of the
15 apparatus illustrated in Figure 9.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is useful in a process for
20 forming soft contact lenses from a polymerizable monomer
or monomer mixture. The soft contact lenses are formed in
a mold assembly having a first concave and a second convex
mold half. As illustrated in Figure 4a, the mold halves
are formed of polystyrene transparent to visible and
25 ultraviolet light, with a central curved section defining
a concave surface 31, a convex surface 33 and circular
circumferential edge 31(c), and integral with said edge an
annular essentially uniplanar flange 31(a). At least a
part of the concave surface 31 and the convex surface 33
30 have the dimensions of the front or back curves,
respectively of a contact lens to be produced in the mold
assembly, and are smooth so that the surface of the
contact lens formed by polymerization of said
polymerizable composition in contact with the surface is

optically acceptable. The mold is thin enough to transmit
1 heat therethrough rapidly and has rigidity sufficient to
withstand prying forces applied to separate the mold
halves during demolding step which occurs after the cure
step in the manufacturing process.

5 The present invention is directed to an
additional precure step introduced between the assembly of
the mold with a polymerizable monomer or monomer mixture,
and the cure step. The precure step partially cures the
polymerizable monomer or monomer mixture to a viscous gel
10 and initiates polymerization throughout the mixture.
During this precure step the parallel alignment of the
mold halves are "frozen" by the viscous gel like nature of
the partially polymerized monomer gel which prevents
decentration and enables unattended and unweighted cure
15 during the remainder of the cure period. The addition of
this precure step has substantially reduced the number of
defective lenses resulting from traditional methods of
manufacture.

The complimentary pair of first 31 and second 33
20 mold halves which define the shape of the final desired
lens are used to direct mold the monomer mixture wherein
the mixture is dissolved in a nonaqueous water displacable
solvent. After the filling or dosing step, in which the
front concave mold half 31 is substantially filled with a
25 polymerization mixture 32, the concave front mold half 31
is covered with a base mold half 33 under a vacuum to
ensure that no air bubbles are trapped between the mold
halves. The base mold half is then brought to rest on the
circumferential edge 31(c) of the concave front mold half
30 to ensure that the resultant lenses are properly aligned
and without distortion.

The first and second mold halves are then
clamped together. This clamping step may be done
following assembly of the mold halves, during precure, or

both. The clamping step displaces any surplus monomer
1 from the mold area and properly aligns the mold halves by
alignment of the mold flanges. When the clamping step
occurs in the precure process, the mold halves are clamped
under pressure, the monomer or monomer mixture is then
5 exposed to actinic light, preferably from a UV lamp, while
the mold halves are clamped. Typically the mold halves
are clamped for approximately 40 seconds with 30 seconds
of actinic radiation. At the completion of the precure
step, the monomer or monomer mixture has formed a
10 partially polymerized gel, with polymerization initiated
throughout the mixture.

Following the novel precure step, the
monomer/diluent mixture is then cured in a UV oven whereby
polymerization of the monomer(s) is completed. This
15 irradiation with actinic, visible or ultraviolet radiation
produces a polymer/diluent mixture in the shape of the
final desired hydrogel lens. After the polymerization
process is completed, the two halves of the mold are
separated in a demolding step typically leaving the
20 contact lens in the first or front curve mold half, from
which it is subsequently removed. The front and base
curve mold halves are used for a single molding and then
discarded or disposed of. After the demolding step, the
solvent is displaced with water to produce a hydrated
25 lens, which when fully hydrated and buffered, will be of
the final shape and size which, in most cases, is
nominally 10% larger than the original molded
polymer/diluent article.

The present invention is therefore a novel
30 precure step, and includes two separate embodiments of an
apparatus for performing the same. The precure step is
inserted in the process immediately after the
polymerizable composition is placed in the front curve
mold half, and the mold halves assembled.

The compositions to which this precure step may
1 be directed include copolymers based on 2-hydroxyethyl
methacrylate ("HEMA") and one or more comonomers such as
2-hydroxyethyl acrylate, methyl acrylate, methyl
methacrylate, vinyl pyrrolidone, N-vinyl acrylamide,
5 hydroxypropyl methacrylate, isobutyl methacrylate,
styrene, ethoxyethyl methacrylate, methoxy
triethyleneglycol methacrylate, glycidyl methacrylate,
diacetone acrylamide, vinyl acetate, acrylamide,
hydroxytrimethylene acrylate, methoxyethyl methacrylate,
10 acrylic acid, methacryl acid, glyceryl methacrylate, and
dimethylamino ethyl acrylate.

Preferred polymerizable compositions are
disclosed in U.S. Patent No. 4,495,313 to Larsen, U.S.
Patent No. 5,039,459 to Larsen et al. and U.S. Patent No.
15 4,680,336 to Larsen et al.

Such
compositions comprise anhydrous mixtures of a
polymerizable hydrophilic hydroxy ester of acrylic acid or
methacrylic acid and a polyhydric alcohol, and a water
20 displaceable ester of boric acid and a polyhydroxyl
compound having preferably at least 3 hydroxyl groups.
Polymerization of such compositions, followed by
displacement of the boric acid ester with water, yields a
hydrophilic contact lens. The mold assembly of the
25 present invention described herein may be used to make
hydrophobic or rigid contact lenses, but the manufacture
of hydrophilic lenses is preferred.

The polymerizable compositions preferably
contain a small amount of a cross-linking agent, usually
30 from 0.05 to 2% and most frequently from 0.05 to 1.0%, of
a diester or triester. Examples of representative cross
linking agents include: ethylene glycol diacrylate,
ethylene glycol dimethacrylate, 1,2-butylene
dimethacrylate, 1,3-butylene dimethacrylate, 1,4-butylene

dimethacrylate, propylene glycol diacrylate, propylene
1 glycol dimethacrylate, diethylglycol dimethacrylate,
dipropylene glycol dimethacrylate, diethylene glycol
diacrylate, dipropylene glycol diacrylate, glycerine
trimethacrylate, trimethylol propane triacrylate,
5 trimethylol propane trimethacrylate, and the like.
Typical cross-linking agents usually, but not necessarily,
have at least two ethylenically unsaturated double bonds.

The polymerizable compositions generally also
include a catalyst, usually from about 0.05 to 1% of a
10 free radical catalyst. Typical examples of such catalysts
include lauroyl peroxide, benzoyl peroxide, isopropyl
percarbonate, azobisisobutyronitrile and known redox
systems such as the ammonium persulfate-sodium
metabisulfite combination and the like. Irradiation by
15 ultraviolet light, electron beam or a radioactive source
may also be employed to catalyze the polymerization
reaction, optionally with the addition of a polymerization
initiator. Representative initiators include
camphorquinone, ethyl-4-(N,N-dimethyl-amino)benzoate, and
20 4-(2-hydroxyethoxy)phenyl-2-hydroxyl-2-propyl ketone.

Polymerization of the polymerizable composition
in the mold assembly is preferably carried out by exposing
the composition to polymerization initiating conditions.
The preferred technique is to include in the composition
25 initiators which work upon expose to ultraviolet or
visible radiation; and exposing the composition to
ultraviolet or visible radiation of an intensity and
duration effective to initiate polymerization and to allow
it to proceed. For this reason, the mold halves are
30 preferably transparent to ultraviolet or visible
radiation. After the precure step, the monomer is again
exposed to ultraviolet or visible radiation in a cure step
in which the polymerization is permitted to proceed to
completion. The required duration of the remainder of the

reaction can readily be ascertained experimentally for any
1 polymerizable composition.

After the polymerizable composition has
polymerized, the mold assembly is disassembled to permit
further processing of the polymerized hydrogel into a
5 contact lens (such processing including e.g. washing and
hydrating, and packaging of the lens). Preferably, the
flanges of the front and back curve mold halves are
gripped and pulled away from each other, either in
directly opposite directions or through an angle in a
10 prying sort of motion. Advantageously, the back curve is
first heated moderately to facilitate separation of the
polymerized article from the back curve mold half
surfaces.

15 The Precure Apparatus

Figure 1 and Figure 2 represent a side elevation
view and an end elevation view, respectively, of an
apparatus for practicing the present invention. As
20 illustrated in Figures 1 and 2, a support frame 11 having
legs 12 provides support for the device at an elevation of
an infeed conveyor 13. As shown in Figure 3, the precure
apparatus receives a plurality of pallets, one of which is
illustrated in Figure 4, having a plurality of contact
25 lens molds therein, from the infeed conveyor 13. As seen
in Figure 3, the infeed conveyor 13 delivers the pallets
30 and molds 31, 33 to a low oxygen environment, which
environment is accomplished by pressurizing an enclosure
14 with nitrogen gas. Prior to polymerization, the
30 monomer is susceptible to absorption of oxygen which
results in degradation of the resultant lens. The
enclosure 14 may be pivoted about pivot point 15 by
lifting on handle member 16. A gas strut assist device 17

will hold the enclosure 14 in an open position for servicing of the apparatus.

As illustrated in Figure 3, the conveyor 13 delivers pallets 30 containing a plurality of molds 31, 33 to an accumulating section generally indicated 18 which gathers a plurality of pallets for the precure step. In the embodiment illustrated in Figures 1-2 and 6-8, twelve pallets of the type illustrated in Figure 4 are accumulated for a total of 96 molds in each batch operation. In the embodiment illustrated in Figures 9 and 10 a total of 12 pallets having 96 contact lens molds thereon are batched for each precure operation. Accumulator 18 thus enables the precure apparatus of the present invention to batch process a plurality of molds for an extended period of time of 30 to 60 seconds while continuously receiving new pallets from the production line at the rate of 1 every 6 to 12 seconds.

The picture assembly 19 is partially visible in the breakaway portion of Figure 1, and is further described with respect to Figures 6-8. It is raised and lowered into engagement with pallets containing contact lens molds by virtue of a pneumatic cylinder 20 which raises and lowers an intermediate support beam 21 and reciprocating shaft members 22 which are journaled for reciprocating support in member 23 as will be hereinafter subsequently described in greater detail. After the precure operation, the pallets with contact lens molds therein are discharged through a nitrogen ventilation airlock mechanism 24 (illustrated in Figure 1) for subsequent cure by heat and cycled actinic radiation.

The present invention is particularly adapted to cooperate with a plurality of pallets as illustrated in Figure 4 and 4a which have a plurality of cavities for receiving a plurality of contact lens molds. As illustrated in Figure 4a, the contact lenses of the

present invention are formed by placing an amount of
1 polymerizable composition, generally on the order of about
60 μ l, in the first or concave mold half 31. The desired
amount depends on the dimensions (i.e., the diameter and
thickness) of the desired lens, taking into account the
5 generation of by-products upon polymerization and exchange
water for those by-products and diluent, if any, following
polymerization.

Then a second or convex mold half 33 is placed
onto the polymerizable composition 32 with the first and
10 second mold halves aligned so that their axes of rotation
are collinear and the respective flanges 31(a), 33(a) are
parallel. The mold halves 31 are carried in an annular
recess 30(a) which receives and supports the annular
flange 31(a) of the first or concave mold half. The
15 pallet 30 also has a plurality of recesses 30(b) for
receiving the concave portion of the mold. The pallet
also carries a plurality of oriented recesses 30(c) which
receive a triangular tab portion 31(c) of the base mold
half to provide a predefined angular position. The second
20 or convex mold half 33 also includes a triangular tab
33(c) which overlies tab 31(c) to provide a collinear axis
of rotation with respect to the two mold halves. The
pallet 30 illustrated in Figure 4 also contains a unique
bar code number 35 for use in pallet tracking and quality
25 control procedures.

Figure 3 is a diagrammatic representation of a
portion of the apparatus more fully illustrated in Figures
6-9 and Figures 9-10 which is particularly suited to an
overview of the present invention. As illustrated in
30 Figure 3, the apparatus includes a conveyor system 13 for
transporting a plurality of pallets 30 into and away from
the precure station. Batch mode forks 36(a), 36(b) are
used to gather and move a plurality of pallets into the
precure apparatus.

The apparatus 19 includes multiple vertical reciprocal movements, a first one of which is in response to movement from air cylinder 20(a) and reciprocating beam 21(a). As the precure apparatus 19 is lowered in the direction illustrated by arrow A, a plurality of annular clamping means 40 will engage the upper annular flange 33(a) of each of the mold halves contained within pallets 30. A plurality of annular clamping means 40 are mounted on and travel with a reciprocating platform 41 of the apparatus, and are resiliently mounted therein for a second reciprocal movement along the directions of arrow B illustrated in Figure 3.

As illustrated in Figure 3, the clamping means 40 are biased within frame 41 by springs 42 (illustrated diagrammatically) which may be the air spring 42(a) illustrated in Figure 5a or a helical spring 42 as illustrated in Figure 5b. As the apparatus is lowered, the clamping means will engage and clamp the first and second mold halves together with the force determined by the spring means 42. When air springs are used, the force will be determined by the amount of pressure provided to the air cylinder 42(a). While clamping means 40 have been illustrated as four members in Figure 3 for illustrative purposes, it is understood that in the embodiments illustrated in Figure 6-8 and the embodiment illustrated in Figures 9-10 that there are 96 individual clamping means, with an individual clamping means for each of the mold halves.

Positioned above the clamping apparatus are a plurality of actinic light sources 44 which may be UV lamps. The lamps are separated from the clamping area by Pyrex glass 100 which separates the precure apparatus into two separate heat zones. This enables cooling of the actinic lamps 44, while maintaining the clamping zone at an optimal cure temperature. The glass 100 also protects

the lamps from monomer emissions which collect on the
1 glass 100 rather than the lamps 44. After the clamping
means has engaged the mold halves to clamp them together,
a shutter mechanism 45 is opened by air cylinder 46 to
enable the actinic light source 44 to initiate
5 polymerization of the polymerizable composition in each of
the mold halves 33. Shutter 45 has a plurality of
openings 43 defined therein and is reciprocal along the x
axis as indicated by arrow C in Figure 3 in order to open
and close the exposure passage ways 47.

10 The operation of the precure apparatus 19 is set
by control circuit 10 which controls the duration of the
clamping period by the length of time air cylinder 20(a)
is activated to its reciprocal down position. Control
circuit 10 also controls the amount of radiation received
15 by the molds controlling the duration of the exposure
period through operation of shutter 45 and air cylinder
46. The intensity may also be manually adjusted by
raising or lowering the lamps 44 with respect to molds
31,33. Optionally, the polymerization radiation may be
20 generated remotely and routed to the clamped mold halves
and polymerizable material via a fiber optic system, with
control system 10 providing control of exposure time and
energy level.

The amount of force applied by clamping means 40
25 may be varied from approximately 0.5 Kgf to 2.0 Kgf/per
lens and is applied to keep the flange 33(a) of the second
convex mold half parallel to the flange 31(a) of the first
concave mold half for the duration of the exposure. The
clamping weight is applied for 10 to 60 seconds, but
30 typically for a period of 40 seconds by control means 10.
After approximately 0-20 seconds of weight, preferably 10
seconds, actinic radiation from UV lamps 44 is applied to
the assembled mold and the polymerizable monomer.
Typically, the intensity of the UV light source is 2-4

mW/cm², and this intensity of light is applied for 10 to 50
1 seconds, but in the preferred embodiment, is applied for
30 seconds.

In the preferred embodiment, the UV lamp source
are tubular low pressure mercury vapor fluorescent lamps
5 which emit a long wave ultraviolet radiation having a
highly concentrated radiation between 320 and 390 nm. In
one embodiment, by way of example, the lamps are
manufactured by Philips as model 'TL' 29 D 16/09 N having
a nominal wattage of 14 watts and an average radiation of
10 1.8 watts in the desired spectrum.

The mold halves are first clamped together for
a predetermined period of time, prior to exposure, in
order to allow equilibrium to develop between the monomer
and the mold cavity, and to allow any excess monomer to be
15 extruded out of the mold cavity into the space between
flanges 31(a) and 32(a) where it forms a ring of excess
monomer 32(a), which is generally referred to as a "HEMA"
ring when hydroxyethylmethacrylate monomer is used. The
first or concave mold cavity includes a sharp annular edge
20 31(c) to cleanly contact the convex portion of mold half
33 and thereby separate the contact lens 32 from the HEMA
ring 32(a). The pre-exposure clamping period allows for
any excess monomer to migrate from the mold cavity to the
HEMA ring, enables the second mold cavity to seat cleanly
25 on parting edge 31(c), and allows an equilibrium to
develop between the mold halves and the monomer.

Although the mold halves may be held together
until the monomer(s) are completely cured, in the
preferred embodiment actinic radiation on the order of 2-4
30 mW/cm² is applied for approximately 30 seconds. Different
intensities and exposure times could be used, including
pulsed and cycled high intensity UV on the order of 10 to
150 mW/cm² with exposure times running from 5 to 60
seconds. In a pulsed or cycled exposure, the actinic-

radiation may be cycled on for 3 to 10 seconds and then
1 off for 3 to 10 seconds with a total of 1 to 10 cycles of
radiation. At the end of the radiation period, the
shutter 45 is closed by reciprocating it to the right as
illustrated in Figure 3 and the weight is removed by
5 energizing cylinder 20(a) to lift the precure assembly 19
upwardly by means of push rods 22(a). As the assembly 19
is lifted, the clamping means 40 will be lifted clear of
the molds and pallets to enable them to be transported out
of the precure means by means of conveyor 13(a). During
10 the precure time, the temperature in the system may be
varied from ambient to 50°C.

At the conclusion of the precure process, the
monomer has gone through initiation and some degree of
polymerization. The resultant product is in a gel state
15 with some areas of the product that have the least
thickness, i.e., the edge, having a higher degree of
polymerization than the body. As the monomer polymerizes
it forms a seal along the parting edge 31(c), which
together with the inherent shrinkage of the monomer from
polymerization, forms a secure mold package that may be
20 cured in atmospheric conditions.

The clamping pressure aligns the mold flanges to
provide substantially parallel alignment of the flanges,
and the seal maintains them in a parallel position which
25 results in improved optical characteristics near the
theoretical maximum of the plastic mold halves. Further,
the clamping, and resultant seal from the partial cure
results in an improved "clean" edge at the circumference
of the lens.

30 Figures 5a and 5b are schematic illustrations of
two alternate means for clamping the mold halves together.
In Figure 5a an air spring is used to displace the
clamping means 40 downwardly with respect to the movement
of reciprocating platform 41. In the embodiment
35

illustrated in Figure 5b, a resilient coil spring 42 is
1 used to drive the clamping means 40 downwardly with
respect to the movement of reciprocating platform 41.

As illustrated in Figure 5a, reciprocating
platform 41 includes a plurality of annular cylinders 40,
5 each of which has an annular flange 51 formed thereon,
which reciprocates within a cylinder defined by spacer
plate 52 to form an air spring or air cylinder 42(a). The
cylinder is vented to atmosphere by vents, one of which is
illustrated at 53 in Figure 5a to enable air pressure in
10 the air cylinder 42(a) to drive the flange 51 and clamping
means 40 downwardly against a stop plate 55 when the air
cylinder 42(a) is pressurized. The carriage 50 also
includes an upper stop member 56 which defines the upper
limit of travel by annular flange 51, and serves as
15 reciprocal bearing support for the clamping means 40. The
upper stop member 56 also defines a plurality of air
plenums, one of which is schematically illustrated at 71,
which provide air pressure for the air cylinder 42(a).

Air pressure is supplied to plenum 71 by
20 solenoid air valve 72 which is activated by control means
10. As indicated previously, the air pressure supplied to
air cylinder 42(a) is variable to generate a clamping
force of 0.5 Kgf to 2.0 Kgf on the annular flange 33(a).
As the reciprocating platform 41 is lowered over the
25 pallet 30 and the contact lens molds, the annular clamping
means 40 engages the annular flange 33(a) formed on the
second or convex mold half to urge it downwardly and clamp
it into engagement with mold half 31. The movement of
reciprocating platform 41 is defined by the movement of
30 the entire assembly 19 as driven by air cylinder 20.

As illustrated in Figure 5b, the annular
clamping cylinder 40 also includes an annular flange 51
which is engaged by a resilient coil spring 42 and driven
downwardly, as illustrated in Figure 5b, against stop

plate 55. The other end of coil spring 42 is mounted
1 within upper stop plate 56(a). Spacer plate 52 and the
upper stop plate 56 provide support and guidance for the
vertical reciprocation of clamping members 40.

The clamping member 40 is formed of stainless
5 steel, and optionally the mass of the clamping members may
be increased to enable the clamping members to clamp by
weight alone, without air or spring assist. However, the
combination of the individual reciprocal clamping means 40
and locally driven resilient biasing means enable precise
10 control of the amount of clamping pressure exerted on the
plastic flanges 33(a) of the upper mold regardless of the
amount of force needed to move the mass of the entire
precure assembly 19.

Figures 6-8 are top side and end elevation views
15 of one embodiment of the apparatus for performing the
present invention. As illustrated in Figures 6-8, the
precure assembly 19 is mounted on reciprocating support
shafts 22 which are journaled for reciprocating motion
within support members 23 which are fixably mounted to a
20 frame. Each of the support members 23 include upper and
lower bearings or journals 23(a), 23(b) to provide for
precision guidance of the reciprocating shafts 22. Shafts
22 are driven by intermediate support frame 21 which is in
turn driven by air cylinder 20 as previously described.

25 The precure assembly 19 is reciprocated
vertically with respect to the upper most surface of the
conveyor 13 illustrated schematically in Figures 7 and 8.
The precure assembly 19 is supported from an upper support
frame 60 from which various operating components are
30 suspended by intermediate support members at each corner
generally illustrated at 61, 62 in Figure 7 and 62, 63 in
Figure 8. These members suspend the reciprocating
platform 41, into which the individual clamping means 40
are fitted for a secondary reciprocation along the same

axis. A separate subframe 65 is mounted on platform 41
1 and provides support for the ultraviolet lamps 44 and the
ballast members 66 which provide the high voltage for the
UV lamps, and the starters 67 which are used to initiate
fluorescence. In one embodiment, by way of example, the
5 ballast members may be BTP 30C05S, as manufactured by
Philips and the starters may be model S2, as manufactured
by Philips. The intermediate support frame 65 may be
lifted free from the reciprocating platform 41 by means of
a plurality of handles 67 which are mounted via straps 68
10 to the intermediate support frame 65. Pyrex glass member
100 separates the lamps 44 from the clamping area to
protect the lamps from monomer emissions, and to enable
the lamps to be cooled, while keeping the precure zone at
a temperature of ambient to 50°C to facilitate
15 polymerization. An oxygen detector 69 is also provided to
monitor the low oxygen environment maintained within the
protective cabinet 14 and an alarm is initiated if the
oxygen content rises to an unacceptable level. Shutter 45
is positioned above the reciprocating platform 41 between
20 the UV lamps 44 and the clamping means 40 and is
reciprocated between its open and closed position by
virtue of air cylinder 46.

The embodiment illustrated in Figures 6-8
utilizes the air cylinder or air springs depicted
25 schematically in Figure 5a with an internal common plenum
formed in the reciprocating platform 41 by means of
passageways in stop plate 56. Thus, each of the 96
clamping members 40 are reciprocated by their respective
air cylinders, which are fed from common plenums, one of
30 which is illustrated in Figure 5a as plenum 71 formed in
the upper stop plate 56.

Figures 9 and 10 depict a second preferred
embodiment for practicing the present invention. As
illustrated in Figures 6-8, the first preferred embodiment

reciprocated the UV lamps and clamping members into and
1 out of engagement with the mold halves and pallets carried
by conveyor means 13. In the embodiment illustrated in
Figures 9 and 10, the UV lamps are stationary, and the
pallets are lifted from the conveyor into engagement with
5 the clamping means for the precure period.

The clamping means utilized by the embodiment
illustrated in Figures 9 and 10 utilizes the clamping
means previously described with respect to Figure 5b. In
this embodiment, a plurality of clamping means 40(a) are
10 mounted above a roller conveyor illustrated in side view
in Figure 10 by rollers 80. A plurality of lifting
standards 81 are positioned between groups of rollers 80
on centers approximate the width of the pallets 30. In
Figure 10, a first row of pallets 30 is depicted resting
15 on rollers 80 with adjoining edges of each of the pallets
aligned along the top of the lifting standards 81.

The pallets 30 are aligned in position by means
of stop means 83 which is lifted by air cylinder 82 during
the loading of the precure apparatus. During loading of
20 the device, the stop means 83 is reciprocated upwardly,
and the requisite number of pallets 30 are advanced into
the precure apparatus. When 6 pallets in each row have
been advanced, a second stop means 84 is lifted by air
cylinder 85 to define a limit on x axis travel as
25 illustrated in Figure 10. A separate air cylinder 87 is
used in cooperation with stop means 83 to align the
adjoining edges of the pallets 30 above the centers of the
lifting standards 81. After the pallets have been
aligned, the lifting standards 81 are reciprocated
30 upwardly by means of intermediate support frame 88 and a
pair of pneumatic motors 90 and 91.

The pallets are reciprocated upwardly to the
position illustrated at 30(a) in Figure 10, in which
position they engage the clamping member 40(a) as

previously described with respect to Figure 5b. Each of
1 the clamping members 40(a) also include a separate
independent and resilient spring 42 for driving clamping
member 40(a) and the upper mold half against the lower
mold half during the precure period.

5 After the pallets and mold halves have been
raised by air cylinders 90, 91, and the first and second
mold halves clamped together by means of clamping means
40(a), a reciprocating shutter 45(a) is shifted as
10 illustrated in Figure 3 to align a plurality of openings
therein with the central openings formed in the clamping
means 40(a) and thereby enable exposure of the monomer in
the mold halves by means of actinic light sources 44(a).

The upper precure assembly 19(a) is fixably
supported by means of support beams 92 and 93. High
15 voltage ballast means 66(a) and starter 67(a) also
initiate and maintain fluorescence within the UV light
source 44(a). The reciprocal subassembly of the
embodiment illustrated in Figures 9 and 10 is mounted on
an intermediate support frame 94 which may be raised and
20 lowered by means of pneumatic cylinder 95 to provide for
cleaning and servicing of the apparatus, and in
particular, the clearing of the individual clamping means
40. Pyrex glass member 101 protects the lamps 44(a) from
monomer emissions, and may be removed for clearing. Glass
25 member 101 also divides the apparatus into two temperature
zones, enabling cooling of lamps 44(a). The intermediate
support frame 94 is guided and aligned with the exposure
assembly 19(a) by means of support rods 95, 96 and
reciprocal bushing members 97, 98.

30 The clamping period and the amount of exposure
to radiation are controlled by control means 10 in the
manner previously described with respect to Figures 3
and 5.

Following the precure of the monomer in mold
1 halves 31,33 the pallets 30 are reciprocated downwardly to
the position illustrated in Figure 10 and advanced by
conveyor rollers 80 to a subsequent conveyor (not shown)
which transports the pallets to the final cure apparatus.

5 While the invention has been particularly shown
and described with respect to the preferred embodiments
thereof, it will be understood by those skilled in the art
that the foregoing and other changes in form and details
may be made therein without departing from the spirit and
10 scope of the invention, which should be limited only by
the scope of the appended claims.

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The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An apparatus for partially curing a polymerizable monomer or monomer
5 mixture to form a soft contact lens, said apparatus comprising:

(a) a clamping member for clamping a first contact lens mold half against a
second contact lens mold half at a precure station for a predetermined
pressure and time, said first and second mold halves having a polymerizable
10 monomer or monomer mixture therebetween;

(b) a radiant energy source for polymerizing said polymerizable monomer or
monomer mixture while said first and second halves are clamped together,
wherein said radiant energy source is movable from a first transport position
15 to a second exposure position for polymerizing said monomer or monomer
mixture; and

(c) a frame for moving said radiant energy source from said first transport
position to said second exposure position.

20

2. An apparatus for partially curing a polymerizable monomer or monomer
mixture as claimed in Claim 1, wherein said apparatus further includes a transport
for intermittently transporting a plurality of contact lens mold halves to and from
said precure station.

25

3. An apparatus for partially curing a polymerizable monomer or monomer
mixture as claimed in Claim 1 wherein said monomer or monomer mixture is
exposed to a quantity of energy during an exposure step, and said apparatus further
comprises a control circuit for controlling the quantity of energy received by said
30 monomer or monomer mixture during said exposure step.

4. An apparatus for partially curing a polymerizable monomer or monomer mixture as claimed in Claim 3 wherein said control circuit controls the duration of said exposure step.

5

5. An apparatus for partially curing a polymerizable monomer or monomer mixture as claimed in Claim 1 wherein said clamping member includes a reciprocating clamping member positioned between said second mold half and said radiant energy source.

10

6. An apparatus for partially curing a polymerizable monomer or monomer mixture as claimed in Claim 1 wherein said clamping member is mounted on said frame and resiliently engages said second mold half as said radiant energy source is moved into said second exposure position.

15

7. An apparatus for partially curing a polymerizable monomer or monomer mixture as claimed in Claim 5 wherein said clamping member includes an annular cylinder having an annular diameter greater than the diameter of the contact lens to be polymerized.

20

8. An apparatus for partially curing a polymerizable monomer or monomer mixture as claimed in Claim 7, wherein said annular cylinder is biased into engagement with said mold halves.

25

9. An apparatus for partially curing a polymerizable monomer or monomer mixture as claimed in Claim 8 wherein bias pressure is 0.5 to 2.0 Kgf/lens of clamping force.

10. An apparatus for partially curing a polymerizable monomer or monomer mixture as claimed in Claim 1 wherein said frame includes a fixed mount for a

30

plurality of lamps which emit actinic radiation, said mount being reciprocal from said first transport position to said second exposure position.

11. An apparatus for partially curing a polymerizable monomer or monomer
5 mixture as claimed in Claim 10 wherein said actinic radiation is emitted by a plurality of ultraviolet lamps at 320 to 390 nm.

12. An apparatus for partially curing a polymerizable monomer or monomer
mixture as claimed in Claim 2 wherein said transport includes a mold carrier for
10 transporting a plurality of mold halves to said second exposure position.

13. An apparatus for partially curing a polymerizable monomer or monomer
mixture as claimed in Claim 12 wherein said transport is intermittently paused when
said energy source is moved to said second exposure position.

14. An apparatus for partially curing a polymerizable monomer or monomer
mixture as claimed in Claim 10 wherein each of said plurality of lamps has a
longitudinal axis, wherein a plurality of mold halves are aligned with said
longitudinal axis during said exposure.

15. A method of partially curing a polymerizable monomer or monomer mixture
to form a soft contact lens, said method comprising:

(a) depositing a polymerizable monomer or monomer mixture in a contact
25 lens mold having a first and a second half with said monomer therebetween;

(b) clamping said first mold half into engagement with said second mold half
with a predetermined pressure;

30 (c) moving a radiation source from a first transport position to a second

exposure position for polymerizing said monomer or monomer mixture, said radiation source being moved by means of a frame; and

5 (d) exposing said monomer or monomer mixture to said radiation source to polymerize said monomer to a partially cured state.

10 16. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 15 wherein steps a - b are conducted in a low oxygen environment.

17. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 15 wherein said monomer is exposed to an actinic, electron beam or radioactive source of energy.

15 18. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 17 wherein said source of energy is an ultraviolet lamp.

20 19. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 18 wherein said monomer is exposed to 2 to 150 mW/cm² of ultraviolet radiation at a wavelength of 320 to 390 nm.

25 20. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 18 wherein said monomer is exposed to 2.4 mW/cm² of ultraviolet radiation at a wavelength of 350nm.

21. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 19 wherein said radiation is set for a time period of 1 to 60 seconds.

30 22. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 20 wherein said radiation step is 20 to 40 seconds.

23. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 15 wherein said mold halves are clamped with a force varied from 0.5 to 2.0 Kgf/per lens.

5

24. A method of curing a polymerizable monomer or monomer mixture to form a soft contact lens, said method comprising:

10 (a) depositing a polymerizable monomer or monomer mixture in a contact lens mold having a first and a second half with said monomer therebetween;

(b) clamping said first mold half into engagement with said second mold half with a predetermined pressure;

15 (c) moving a radiation source from a first transport position to a second exposure position for polymerizing said monomer or monomer mixture, said radiation source being moved by means of a frame; and

20 (d) exposing said monomer or monomer mixture to radiation to polymerize said monomer to a cured state.

25. A method of partially curing a polymerizable monomer or monomer mixture to form a soft contact lens, using an apparatus comprising:

25 (a) a transport for intermittently transporting a plurality of contact lens molds through a precure station, each of said contact lens molds having first and second mold halves with a polymerizable monomer therebetween;

30 (b) a clamping member for clamping said first mold half against said second mold half for a predetermined pressure and time;

(c) a radiant energy source for polymerizing said polymerizable monomer while said first and second halves are clamped together; and

5 (d) a control circuit for setting said predetermined pressure and time.

26. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 25 wherein said monomer or monomer mixture is exposed to a quantity of energy during an exposure step, and said control means further comprises
10 a means for varying the quantity of energy received by said monomer during said exposure step.

27. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 25 wherein said control circuit controls the duration of the
15 exposure step.

28. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 25 wherein said clamping member is positioned between said molds and said radiant energy source.
20

29. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 25, in which said transport is movable from a first transport position to a second exposure position for polymerizing said monomer.

25 30. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 29 wherein said clamping member is resiliently mounted and said transport moves said molds into resilient engagement with said clamping member as said molds are moved into said exposure position.

30 31. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 28 wherein said clamping member includes an annular cylinder

having an annular diameter greater than the diameter of the contact lens to be polymerized.

32. A method of partially curing a polymerizable monomer or monomer mixture
5 as claimed in Claim 31 wherein said annular cylinder is resiliently biased into engagement with said mold.

33. A method of partially curing a polymerizable monomer or monomer mixture
as claimed in Claim 32 wherein said clamping pressure is 0.5 to 2.0 Kgf/per lens.
10

34. A method of partially curing a polymerizable monomer or monomer mixture
as claimed in Claim 25 wherein said apparatus includes a fixed mount for a plurality
of lamps which emit actinic radiation, with said transport being reciprocal from a
transport position to an exposure position.

15 35. A method of partially curing a polymerizable monomer or monomer mixture
as claimed in Claim 34 wherein said actinic radiation is emitted by a plurality of
ultraviolet lamps at 320 to 390 nm.

20 36. A method of partially curing a polymerizable monomer or monomer mixture
as claimed in Claim 29 wherein said apparatus includes a plurality of clamping
members and said transport includes a plurality of mold pallets for transporting a
plurality of mold halves to said exposure position.

25 37. A method of partially curing a polymerizable monomer or monomer mixture
as claimed in Claim 36 wherein said pallets means are intermittently reciprocated
towards said energy source to said second exposure position.

30 38. A method of partially curing a polymerizable monomer or monomer mixture
as claimed in Claim 36 wherein said transport includes a plurality of lifting standards
for raising said pallets into engagement with said plurality of clamping members.

39. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 38 wherein said clamping member includes an annular clamping member positioned between said lifting standards and said radiant energy source.

5

40. A method of partially curing a polymerizable monomer or monomer mixture as claimed in Claim 39 wherein said clamping member is resiliently biased and moves from an engagement position to an exposure position when clamping said mold halves.

10

41. A method of curing a polymerizable monomer or monomer mixture to form a contact lens, said method comprising the steps of:

15 (a) depositing a polymerizable monomer or monomer mixture in a contact lens mold having a first and a second half with said monomer therebetween, each of said mold halves having an annular flange;

20 (b) clamping said first mold half into engagement with said second mold half with a predetermined pressure with said annular flanges of said mold halves substantially parallel;

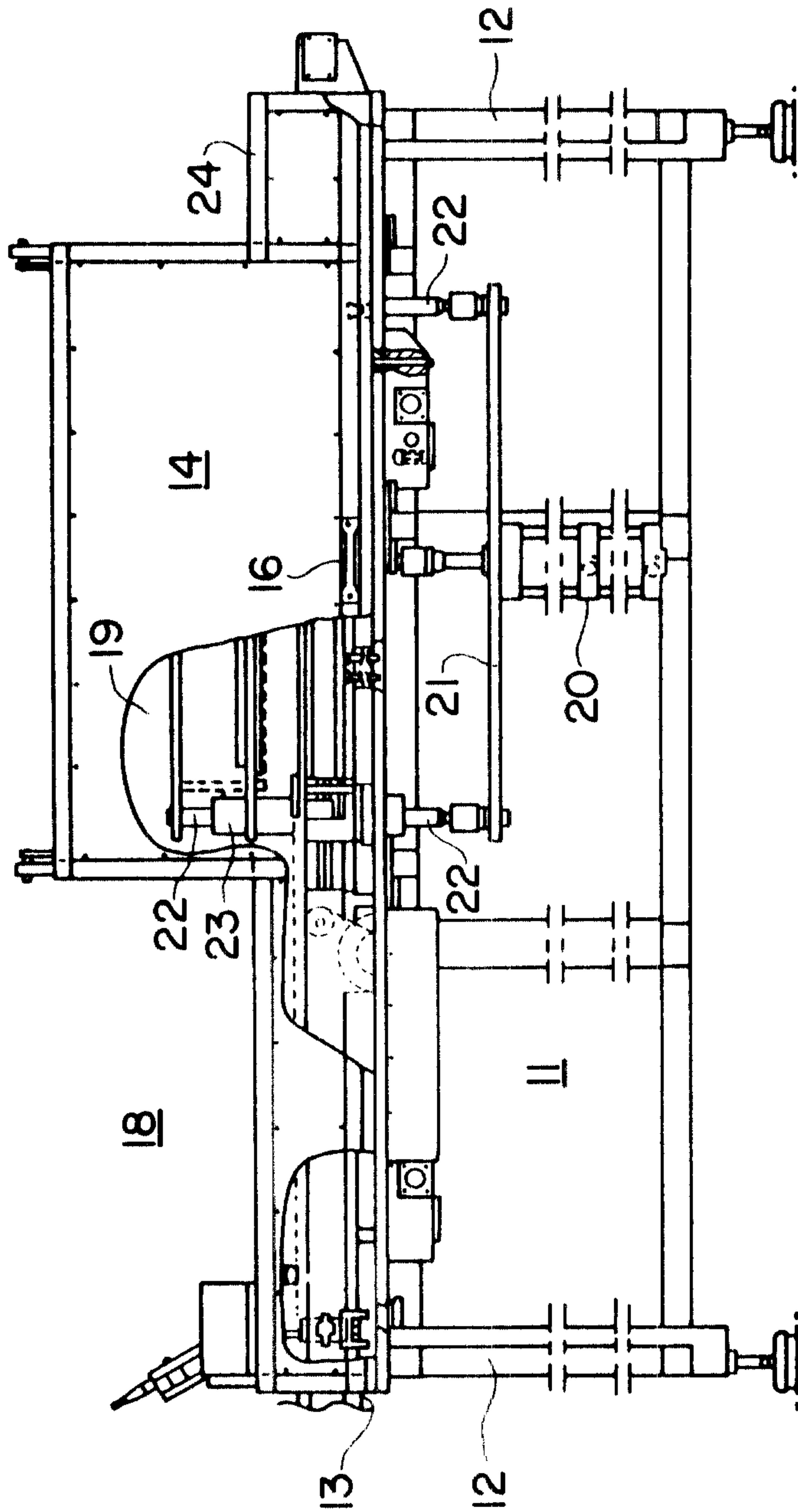
25 (c) moving a radiation source from a first transport position to a second exposure position for polymerizing said monomer or monomer mixture, said radiation source being moved by means of a frame;

(d) exposing said monomer or monomer mixture to radiation to polymerize said monomer to a partially cured state to seal said mold halves together, in alignment, for a subsequent cure step.

30 42. A method of curing a polymerizable monomer or monomer mixture as

claimed in Claim 41 wherein said clamping step forms a clean lens edge for said contact lens.

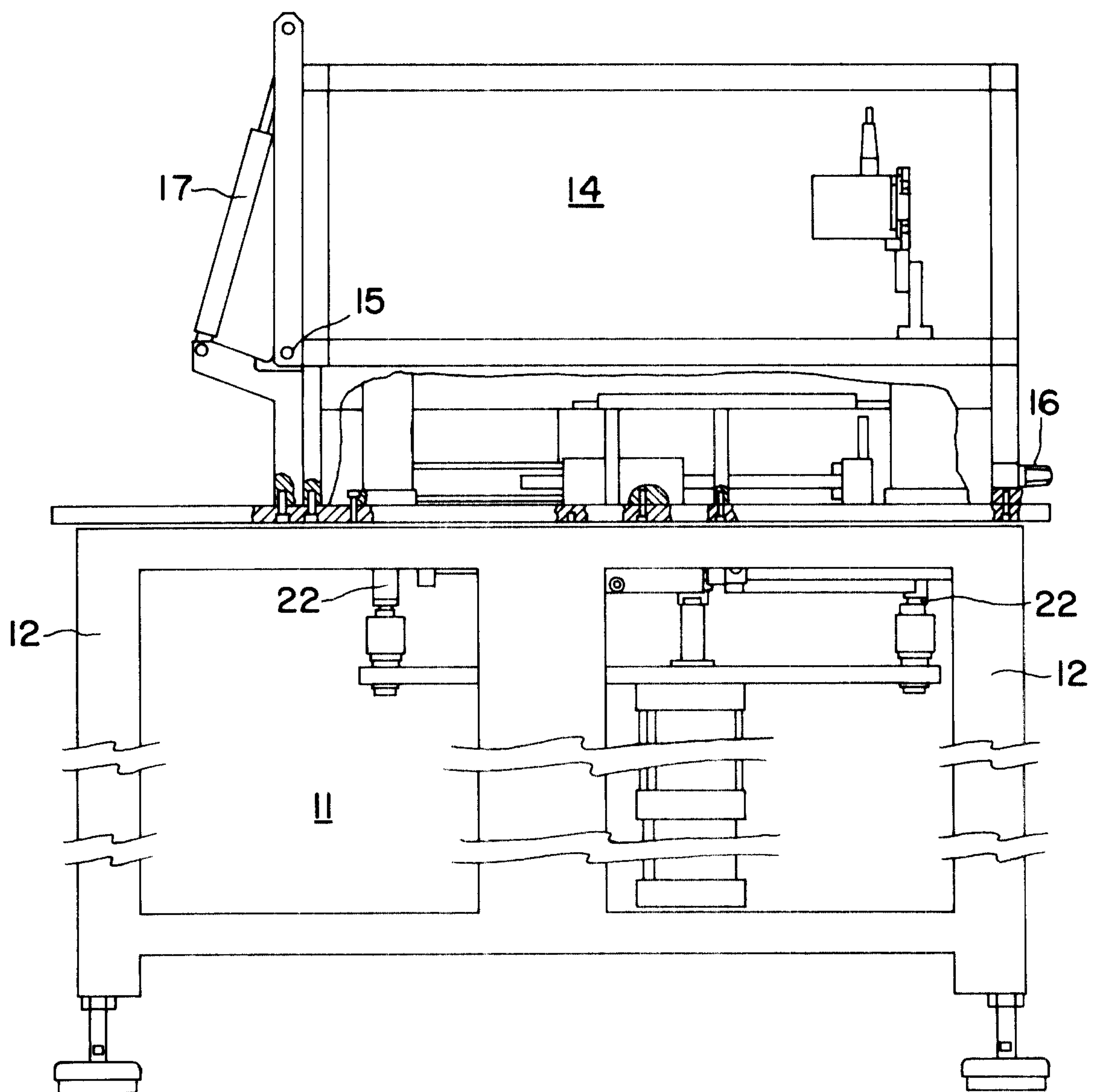
FIG.1



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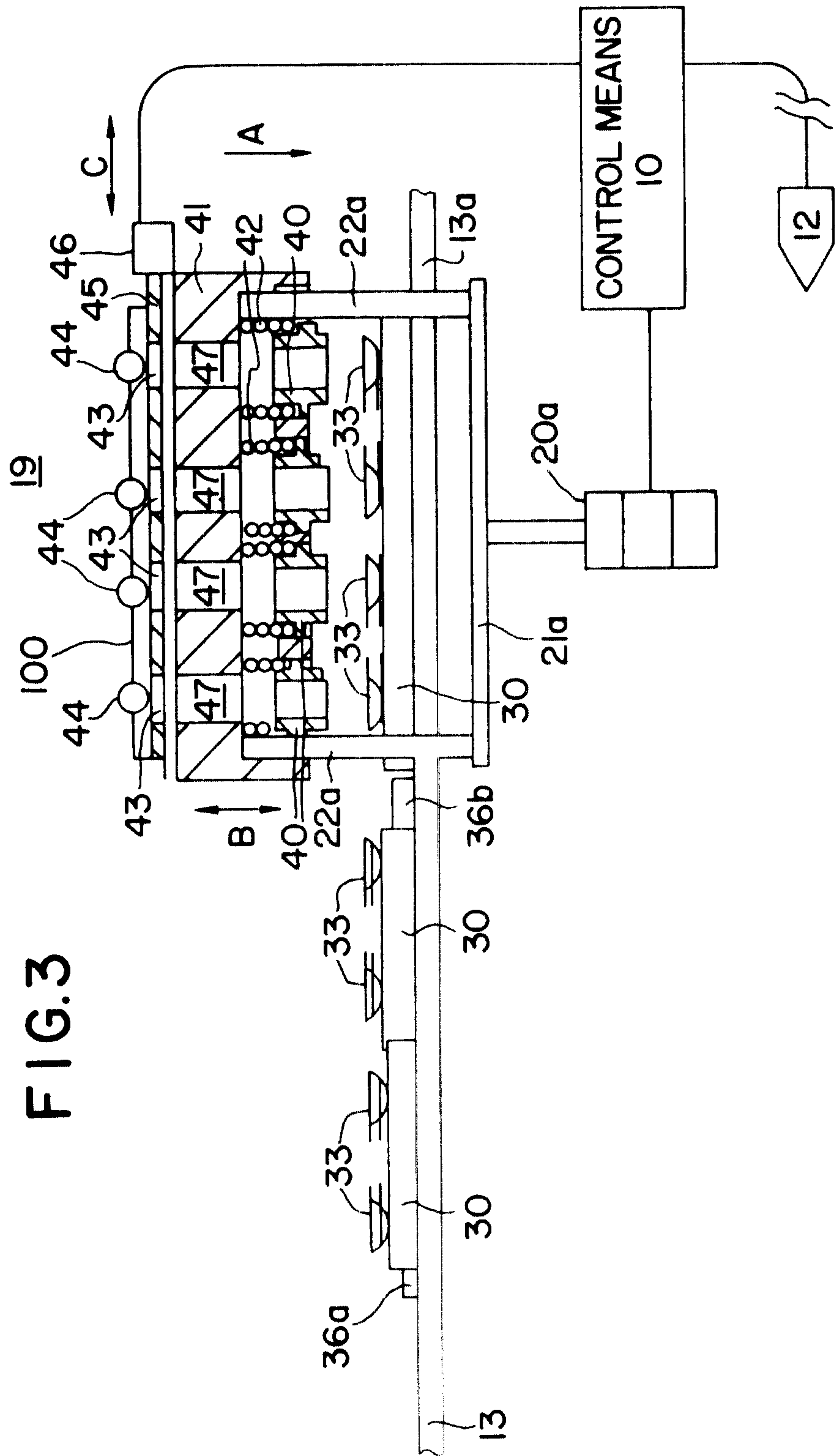
Amhey Ogilvy Renault

FIG. 2



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Dwight Ogilvy Renault



PATENT AGENTS

Awakey Ogilvy Renault

FIG. 4A

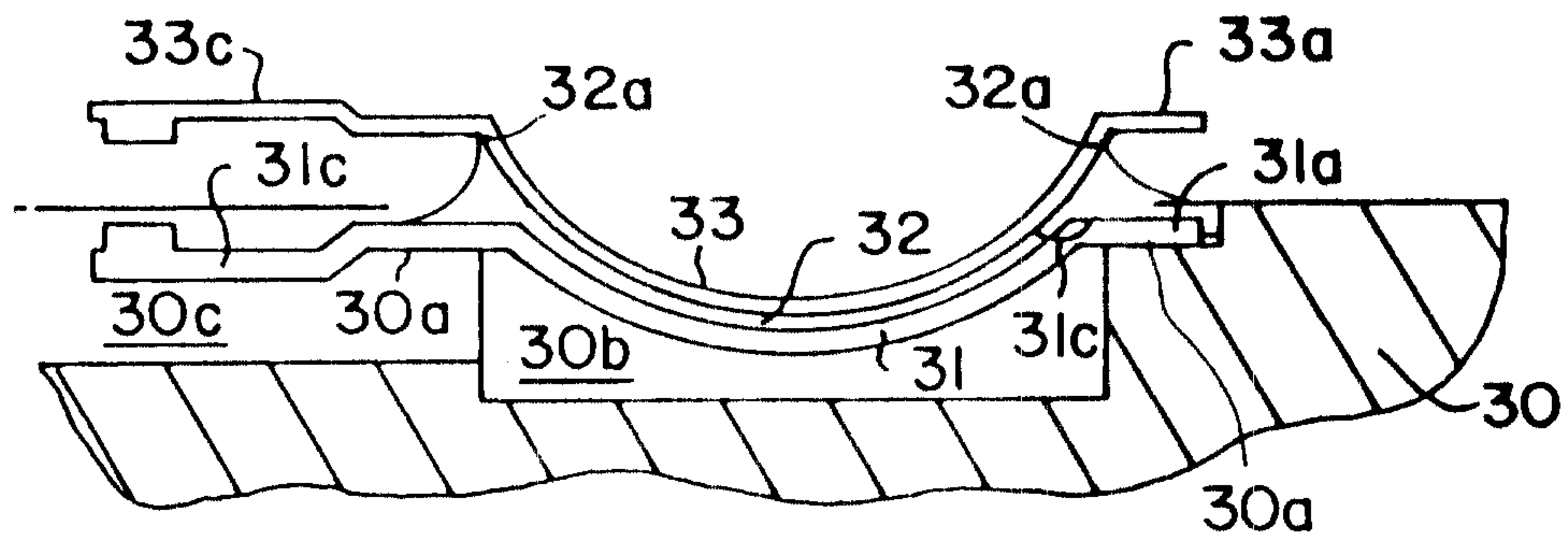
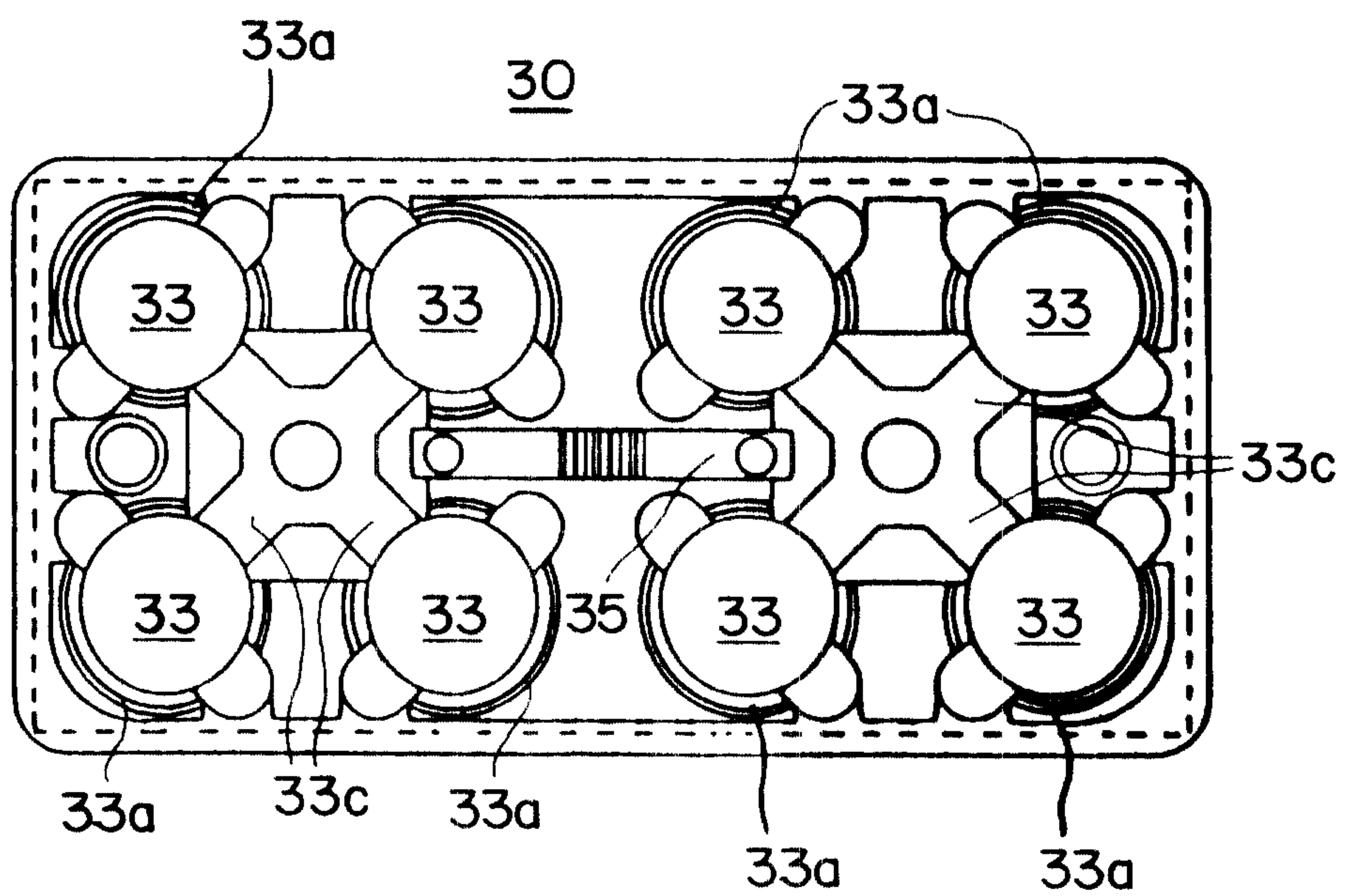


FIG. 4



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FIG. 9

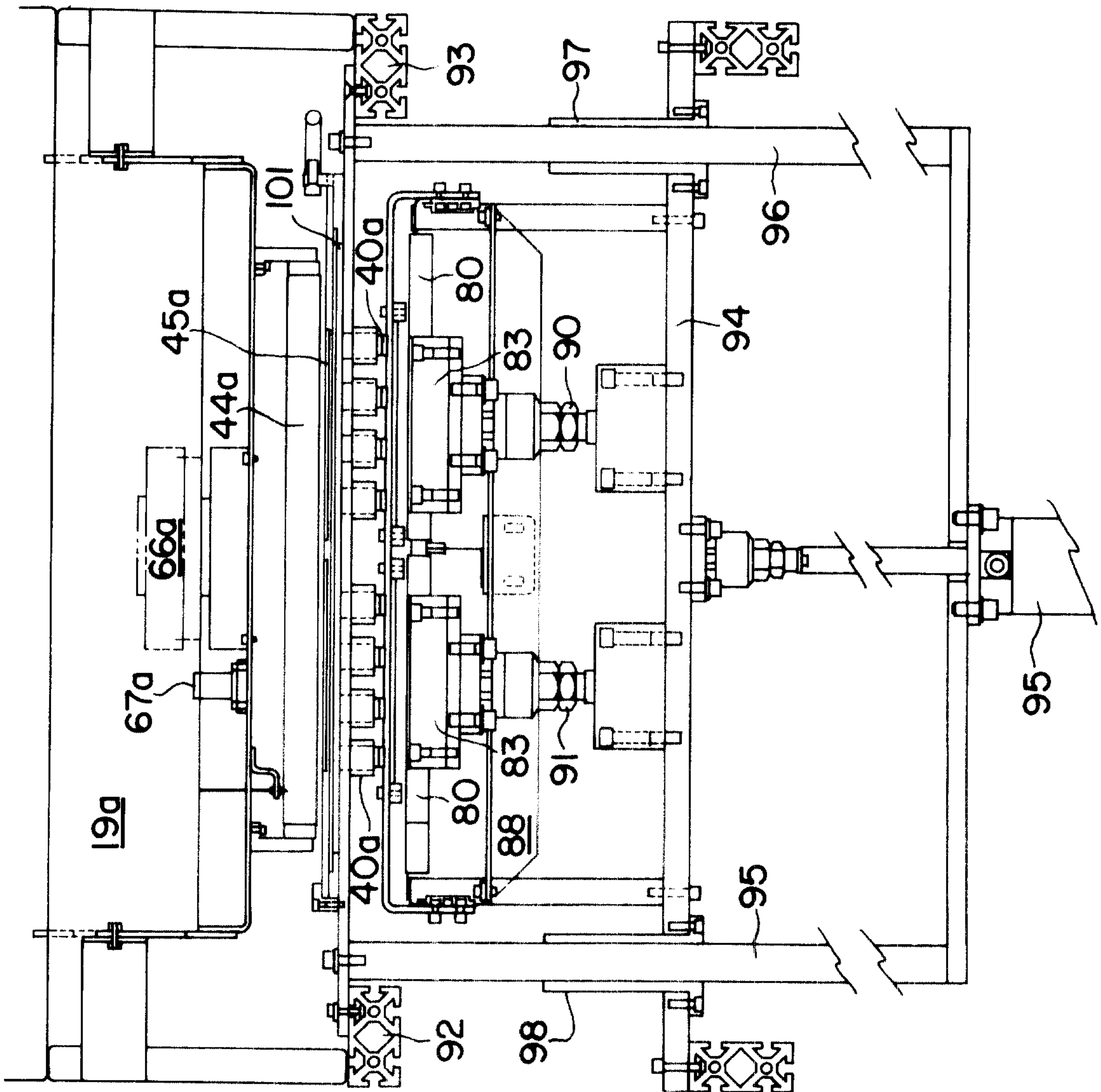


FIG. 5A

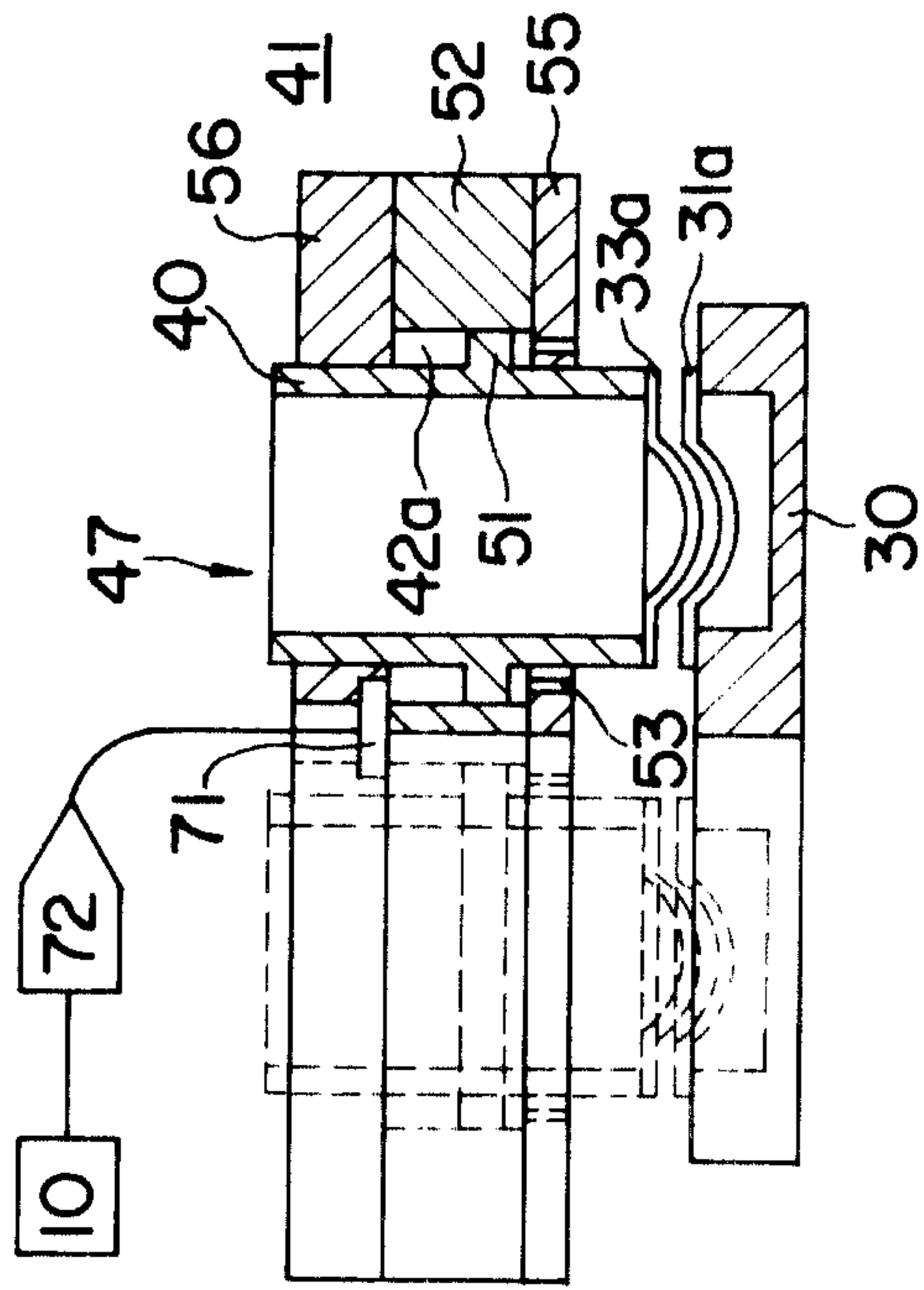
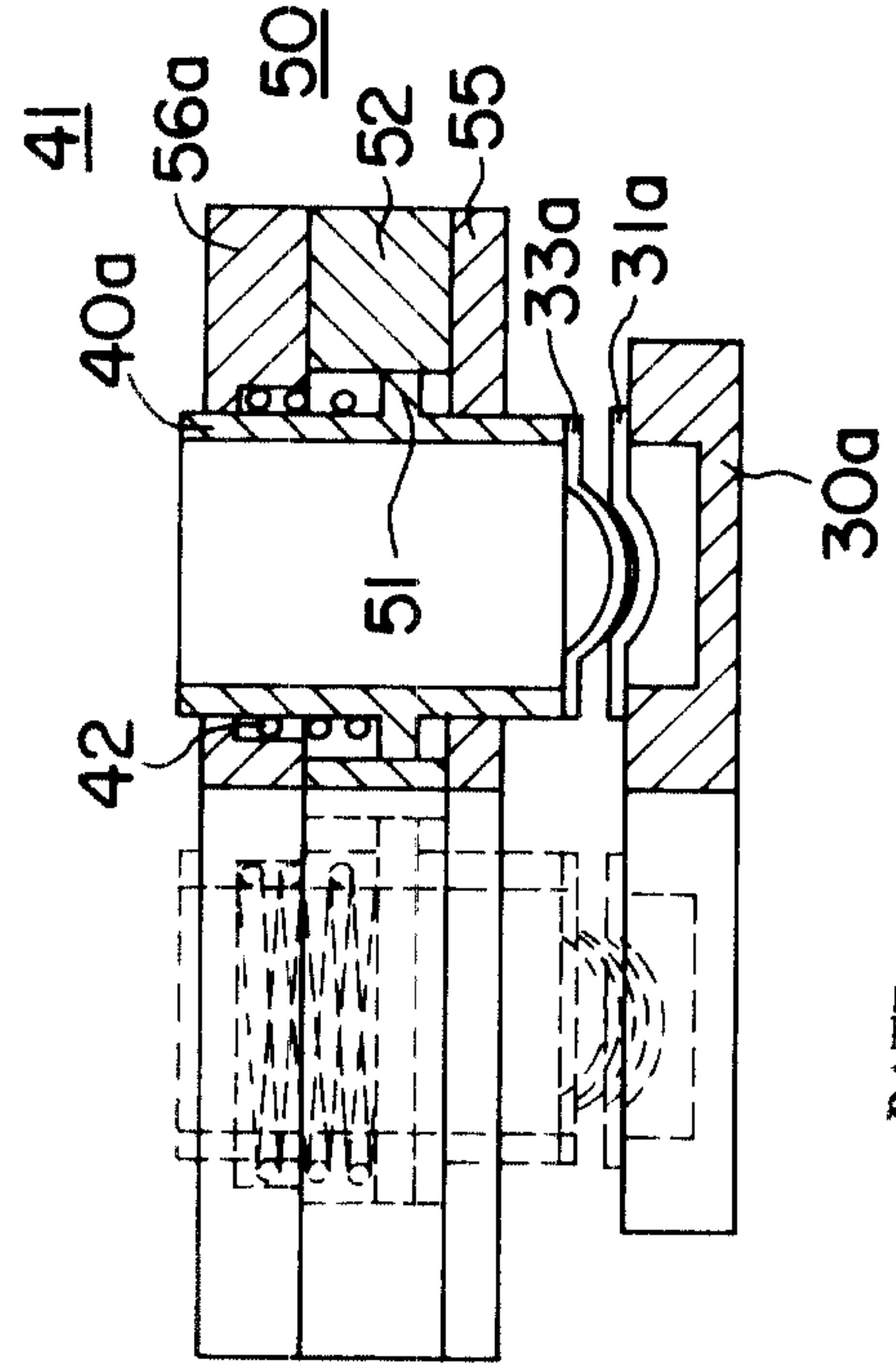


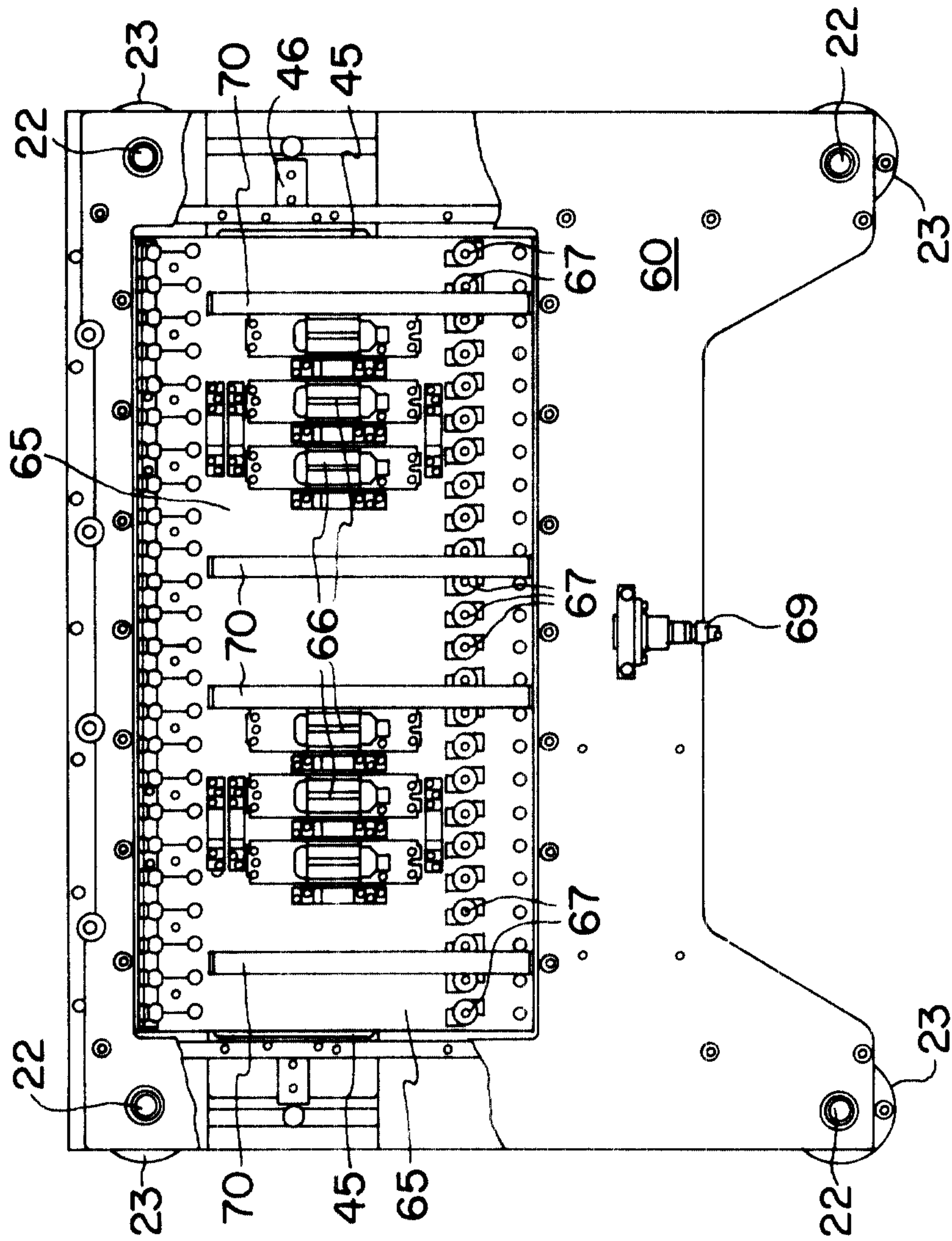
FIG. 5B



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Awabey Ogilvy Renault

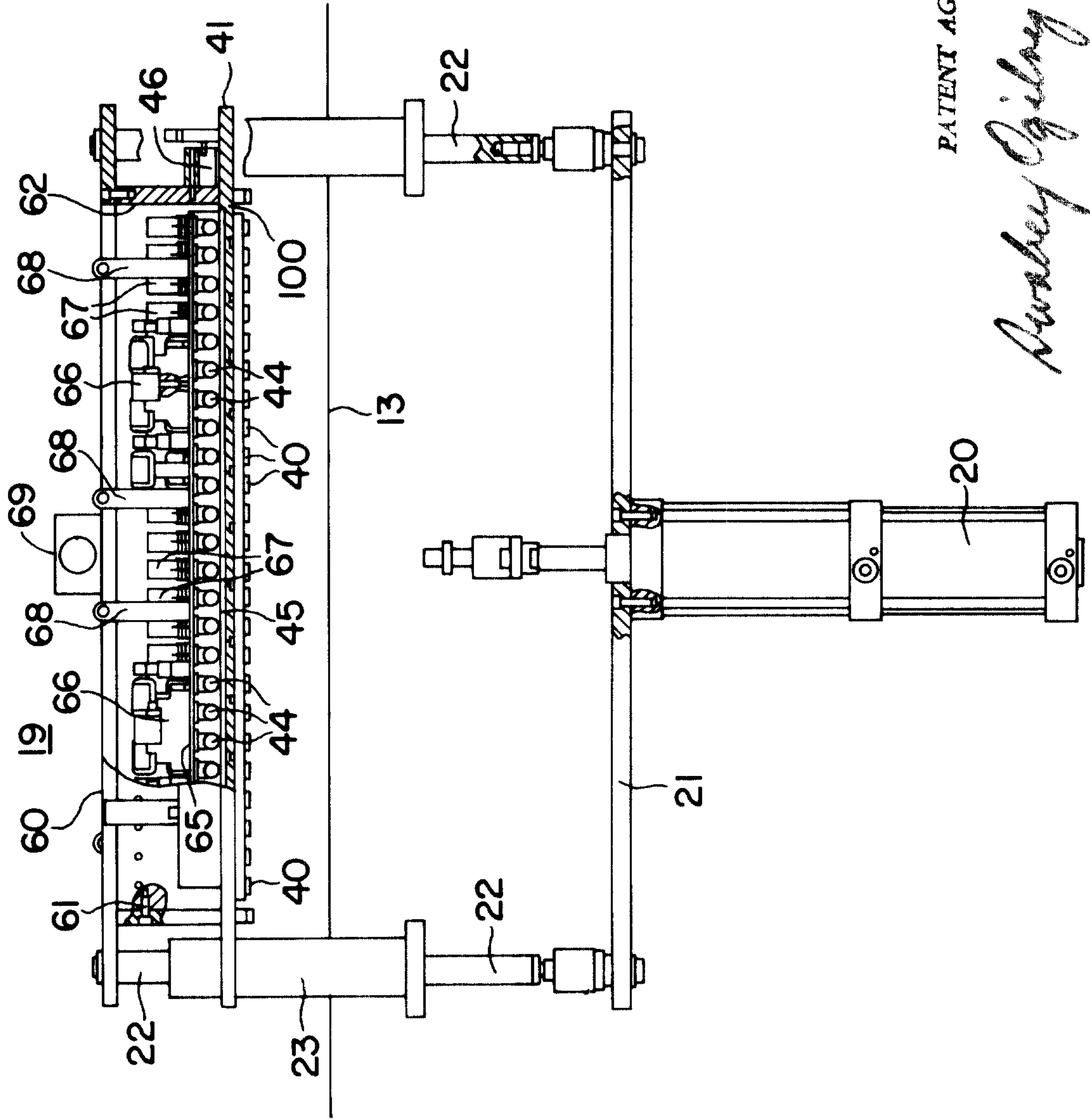
FIG. 6



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Amber Gyling Renault

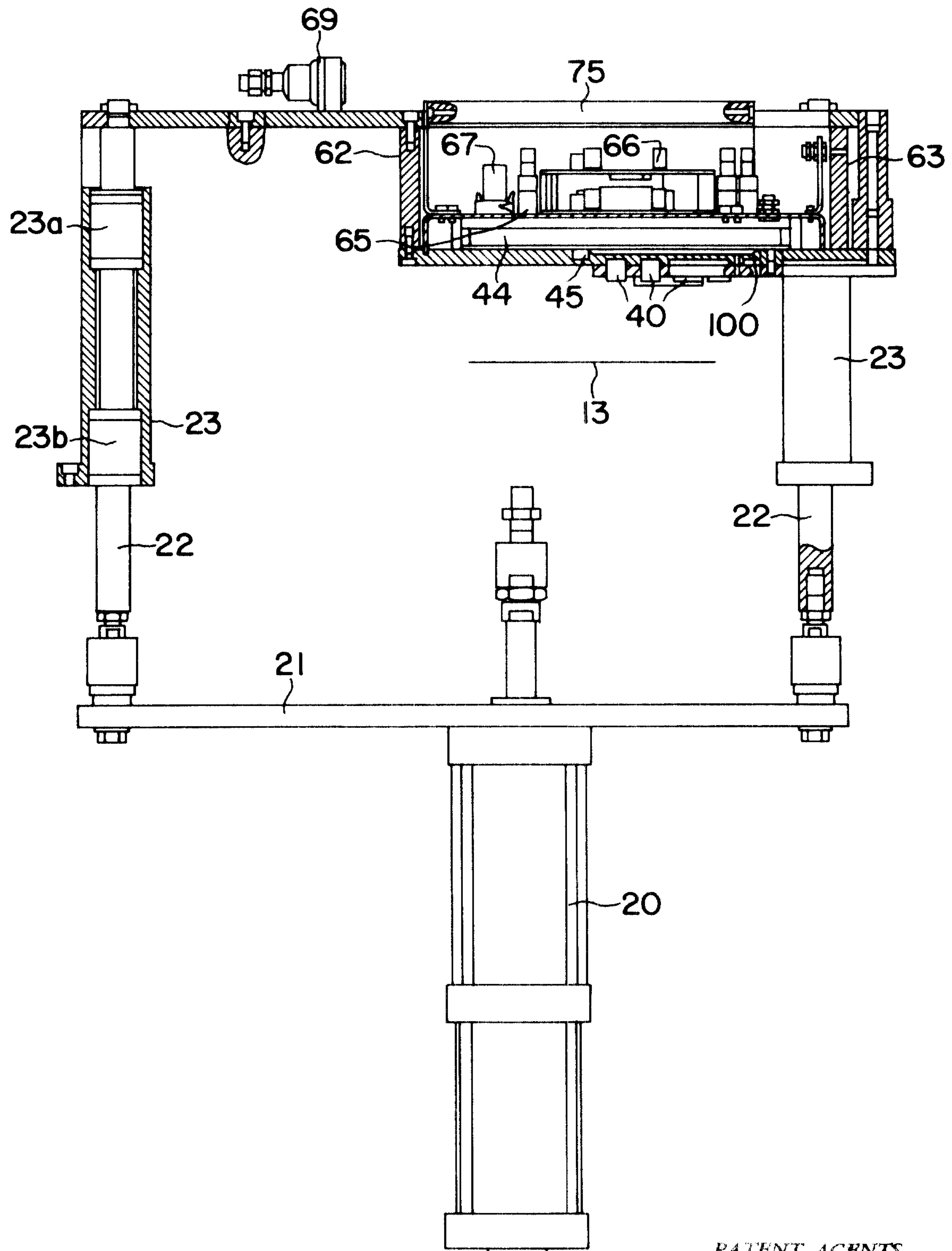
FIG.7



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Swathey Ogilvy Renault

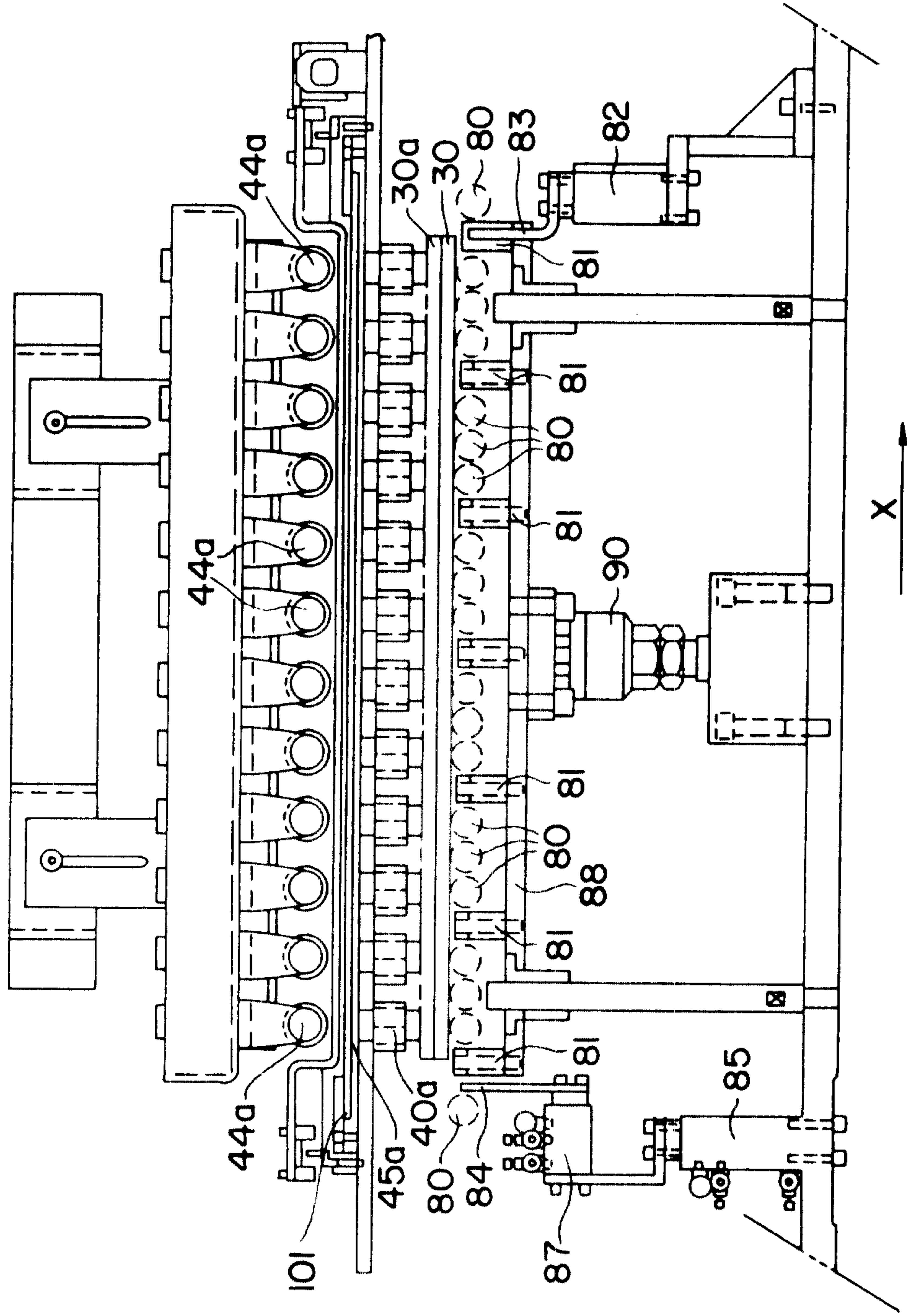
FIG.8



PATENT AGENTS

Rwabeey Ogilvy Renault

FIG.10



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Handing Cycling Renault

